

Water Pollution and the Rising Threat of Antimicrobial Resistance

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Abstract

Water pollution has emerged as one of the most serious environmental and public health challenges worldwide. Rapid industrialization, urbanization, agricultural intensification, and improper waste disposal have led to the contamination of rivers, lakes, groundwater, and other aquatic ecosystems. Polluted water contains harmful substances such as heavy metals, pharmaceutical residues, pesticides, plastics, pathogenic microorganisms, and untreated sewage, which adversely affect human, animal, and environmental health. In recent years, growing evidence has highlighted the strong association between water pollution and antimicrobial resistance (AMR). Aquatic environments contaminated with antibiotics and resistant microorganisms act as reservoirs for the development and dissemination of resistance genes among bacterial populations. Hospital effluents, pharmaceutical waste, livestock runoff, and domestic sewage contribute significantly to the spread of resistant pathogens in water bodies. These resistant microorganisms can enter the food chain and infect humans and animals, making treatment of common infectious diseases increasingly difficult. Water pollution also disrupts aquatic biodiversity, reduces water quality, and threatens ecosystem stability. Effective wastewater treatment, rational antibiotic usage, improved sanitation, strict environmental regulations, and public awareness are essential to minimize the spread of antimicrobial resistance through contaminated water systems. A multidisciplinary One Health approach integrating human, animal, and environmental health is necessary to control this growing global threat and ensure sustainable management of water resources for future generations.

Keywords: Water pollution; Antimicrobial resistance; Antibiotic residues; Wastewater contamination; One Health; Resistant bacteria

Introduction

Water is one of the most valuable natural resources and is essential for the survival of all living organisms. Clean water supports agriculture, livestock production, industry, domestic activities, and ecological balance. However, increasing industrialization, urbanization, and human population growth have resulted in severe contamination of water bodies across the world. Rivers, lakes, ponds, groundwater, and oceans are continuously being polluted with chemicals, sewage, pharmaceutical residues, plastics, and agricultural runoff. Water pollution not only damages the environment but also creates serious public health concerns. In recent years, scientists and health professionals have become increasingly concerned about the relationship between water pollution and antimicrobial resistance (AMR). Antimicrobial resistance occurs when bacteria, viruses, fungi, and parasites develop the ability to survive against medicines that were once effective against them. Polluted water acts as an important reservoir for resistant microorganisms and resistance genes, allowing them to spread rapidly among humans, animals, and the environment. This has transformed

water pollution from merely an environmental issue into a major global health challenge.

Sources of Water Pollution and Their Role in Resistance Development

The contamination of water resources originates from multiple sources. Industrial effluents released from pharmaceutical industries often contain antibiotic residues, heavy metals, and toxic chemicals. These substances create selective pressure in aquatic environments, encouraging the survival and multiplication of resistant bacteria. Similarly, untreated hospital wastewater contains pathogens, antibiotic-resistant organisms, and drug residues that enter rivers and drainage systems without proper treatment. Agricultural activities also play a significant role in water contamination. Antibiotics are frequently used in livestock and poultry production for treatment, prevention, and growth promotion. Residues of these drugs, along with resistant bacteria present in animal excreta, reach nearby water bodies through runoff and improper waste disposal. Aquaculture farms also contribute to the problem because antibiotics used in

fish farming directly contaminate aquatic ecosystems. Domestic sewage is another major contributor. In many developing countries, untreated or partially treated sewage is discharged directly into rivers and lakes. Human waste often contains resistant microorganisms and antibiotic residues that mix with environmental bacteria. Over time, these organisms exchange resistance genes through horizontal gene transfer, resulting in the emergence of multidrug-resistant pathogens. Plastic waste and microplastics present in water bodies further worsen the situation. Studies suggest that microplastics provide surfaces where bacteria can attach, grow, and exchange resistance genes more efficiently. Thus, polluted water becomes an ideal environment for the evolution and spread of antimicrobial resistance.

Impact on Human Health and the Environment

The relationship between water pollution and antimicrobial resistance has serious consequences for both human and animal health. Consumption of contaminated water can expose people to resistant bacteria that cause diseases difficult to treat with conventional antibiotics. Waterborne infections such as typhoid, cholera, urinary tract infections, and gastrointestinal diseases are becoming increasingly challenging due to resistance against commonly used antimicrobial drugs. Hospitals around the world are reporting rising numbers of infections caused by multidrug-resistant organisms. If antimicrobial resistance continues to increase, routine medical procedures such as surgeries, organ transplantation, and cancer chemotherapy may become extremely risky because antibiotics may no longer be effective in preventing infections. The environmental impact is equally alarming. Polluted water affects aquatic organisms by reducing dissolved oxygen levels and altering ecosystem balance. Fish and other aquatic animals exposed to pollutants may accumulate toxic substances and resistant bacteria in their tissues. Wildlife species dependent on contaminated water sources may also act as carriers of resistant pathogens, contributing to the spread of resistance across ecosystems. The livestock sector is also vulnerable. Animals consuming polluted water may develop resistant infections, leading to reduced productivity and increased treatment costs. Resistant pathogens can then spread from animals to humans through direct contact, food products, or environmental contamination, highlighting the importance of the One Health approach.

Prevention and Strategies to Control the Problem

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Addressing water pollution and antimicrobial resistance requires coordinated global action involving governments, industries, healthcare professionals, veterinarians, farmers, and the general public. One of the most important measures is the proper treatment of industrial and hospital wastewater before discharge into the environment. Advanced wastewater treatment technologies can significantly reduce antibiotic residues and resistant microorganisms in water systems. The irrational and excessive use of antibiotics in human medicine, veterinary practice, and agriculture must be strictly controlled. Antibiotics should only be used under professional supervision, and unnecessary use for growth promotion in livestock should be discouraged. Strengthening antimicrobial stewardship programs can help minimize resistance development. Improvement in sanitation and sewage management is essential, particularly in developing regions where untreated sewage commonly contaminates water bodies. Public awareness campaigns should educate people about responsible disposal of medicines and the environmental impact of antibiotic misuse. Regular monitoring of water quality and surveillance of antimicrobial resistance patterns should be implemented at national and international levels. Research institutions should also focus on developing eco-friendly alternatives, rapid diagnostic tools, and sustainable wastewater management systems. Adopting the One Health concept is crucial because human health, animal health, and environmental health are interconnected. Collaborative efforts among medical doctors, veterinarians, environmental scientists, and policymakers can help tackle this growing crisis more effectively.

Conclusion

Water pollution has evolved into a multidimensional global issue that threatens environmental sustainability, public health, and economic stability. Its contribution to the emergence and spread of antimicrobial resistance has added a dangerous new dimension to the problem. Polluted water bodies serve as breeding grounds for resistant microorganisms, allowing them to spread rapidly among humans, animals, and ecosystems. If immediate and effective interventions are not implemented, antimicrobial resistance may become one of the leading causes of mortality worldwide in the coming decades. Protecting water resources, ensuring rational use of antibiotics, improving sanitation, and promoting environmental awareness are essential steps toward safeguarding future generations. Clean water is not only a necessity for life but also a critical defense against the growing threat of antimicrobial resistance.

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